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EXPERIMENTAL ECOLOGICAL SYSTEM "ETEKOS"

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Due to the intensive effect of production activity of people on the environment interest is growing in the fundamental problems of ecology that can only be solved by the joint efforts of scientists of different specialties: biologists, physicists, chemists, etc. By now the main mass of information on the ecosystems has been obtained as a result of observations in nature. However observation is the first, but far from the most effective method of study. Observation, as a rule, does not permit an evaluation of the behavior of the ecosystem under extreme conditions occurring with a drastic change in the physical or chemical parameters of the medium, for example, with local changes in the climate characteristics. Such changes occur at the sites of location of powerful heat sources (large cities, powerful thermal and nuclear plants), where an average increase in the temperature of air and water is noted in the reservoir-coolers of multiple purpose by several degrees. Thus, large thermal power plants with output of 2 million kw create a stream of warm water that continually enters the reservoir and is of roughly the same scale as the Moscow or South Bug Rivers. Here the average heating is about 10°. The nuclear plants require for their cooling 2-4 times more water than the normal thermal plants [2]. /95**

The influx of considerable masses of warm water inevitably leads to a change in the ecological conditions in the reservoirs. We note that these changes are not mandatorily harmful, however it is always necessary to make a thorough analysis and prognosis of the possible changes in order to be ready for them.

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The first experimental ecosystems consisted of microscopic organisms. In 1912 Vudreff [1] for the first time gave a quantitative description of the succession of populations of the Protozoa in a hay extract. A further development of such type of experiments is the studies of closed microcosms (volumes of 250 ml and more) that require only light energy [5], and study of groupings of organisms that develop in chemostats and turbidostats of different types with controllable influx and efflux of the nutrients [4]. In these systems the spatial heterogeneity of different physical and chemical properties of the medium was completely excluded. Therefore recently artificial systems have been created that are a transition between the laboratory microcosms and the natural worlds [3].

In the Moscow University the efforts of the scientists from the physics, biological and geological departments have created an experimental ecosystem in a special basin of the hydrophysics laboratory of the physics department. Figure 1 presents the general scheme of the unit.

In the aqueous ecosystems an important role in the formation of their structure is played by the physical factors such as vertical distribution of illumination intensity and temperature, intensity of turbulent exchange at different depths. Therefore the experimental basin must be of sufficient dimensions. The basin in the hydrophysical laboratory satisfies these criteria. It is a reservoir of volume $36\ m^3$ (3 x 4 x 3). The basin itself and the air chamber above it are insulated from the environment. The water can be heated from below and cooled from above so that by means of convection in the system conditions can be created that are stable in time and uniform in space as occurs in chemostats. However, such a pattern, as a rule, is rarely realized in nature. Therefore it is more expedient to have a medium that is stratified in respect to temperature, illumination intensity and intensity of the turbulent exchange. For this the illumination intensity and heating are regulated with the help of a soffit made of 56 fluorescent lamps of 40 w each. The light falling at an angle to the horizon is created by two lamps that simulate the solar spectrum on the upper boundary of the atmosphere, so that it is possible to evaluate the effect of the solar ultraviolet radiation on the ecosystem. These lamps can be moved on guides which look like circles. Thus, potentialities of the system make it possible to create in the basin different vertical profiles of intensity of illumination with respect to the depth and to regulate the composition of the incident light in certain limits. /96

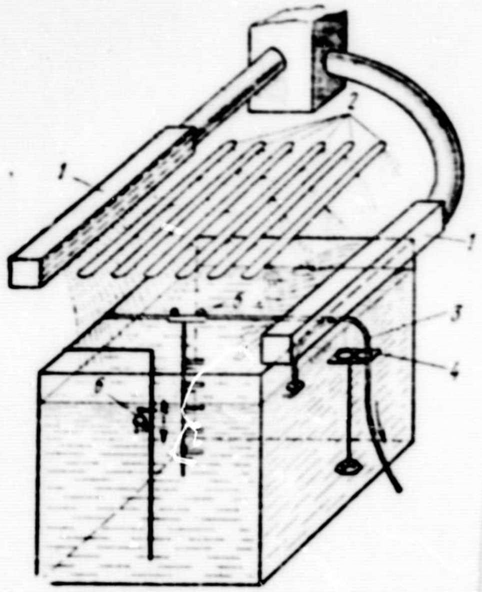

Figure 1. Scheme of Experimental Unit "ETEKOS"
1--system of air conditioning; 2--controllable illumination system; 3--sample taker; 4--meter of underwater illumination intensity; 5--movable post with thermal oxymeters; 6--system for probing pH, eH, dissolved oxygen and temperature.

With the help of the conditioner one can maintain a certain temperature and humidity in the air chamber, and at the same time regulate the intensity of the convective exchange in water with cooling from above. By combining the conditions of illumination and cooling, it is easy to obtain the classic temperature profile of the reservoir with thermocline and area of mixing where the temperature is not altered with depth.

Analogously to the manner this is done in chemostats we can introduce into the system in different concentrations biogenic elements, and also reduce their quantity by adding distilled water. Therefore the given unit is convenient for studying the successions occurring, for example, in eutrophication of reservoirs.

An important component of the unit is the original measuring complex that makes it possible to trace the state of the ecosystem. All the measured parameters can be separated into three groups. The first includes physical and chemical parameters whose recording is completely automated. These are temperature and illumination intensity at different depths, pH values and the oxidation-reduction potential, concentration of dissolved oxygen. The results of the measurements are recorded by a self-recorder. The other group of parameters is the concentration of different biogenic components. In principle their measurement can be automated, however now the chemical analyses are made by colleagues. With the help of the sampler--polyethylene pipe 0.8 cm in diameter-- samples are taken from a certain level and they are sent to the chemical laboratory. The hydro- /98
chemical analyses include certain organic and mineral forms of phosphorous and nitrogen, dissolved silicic acid, indices of alkalinity, dissolved amino acids,

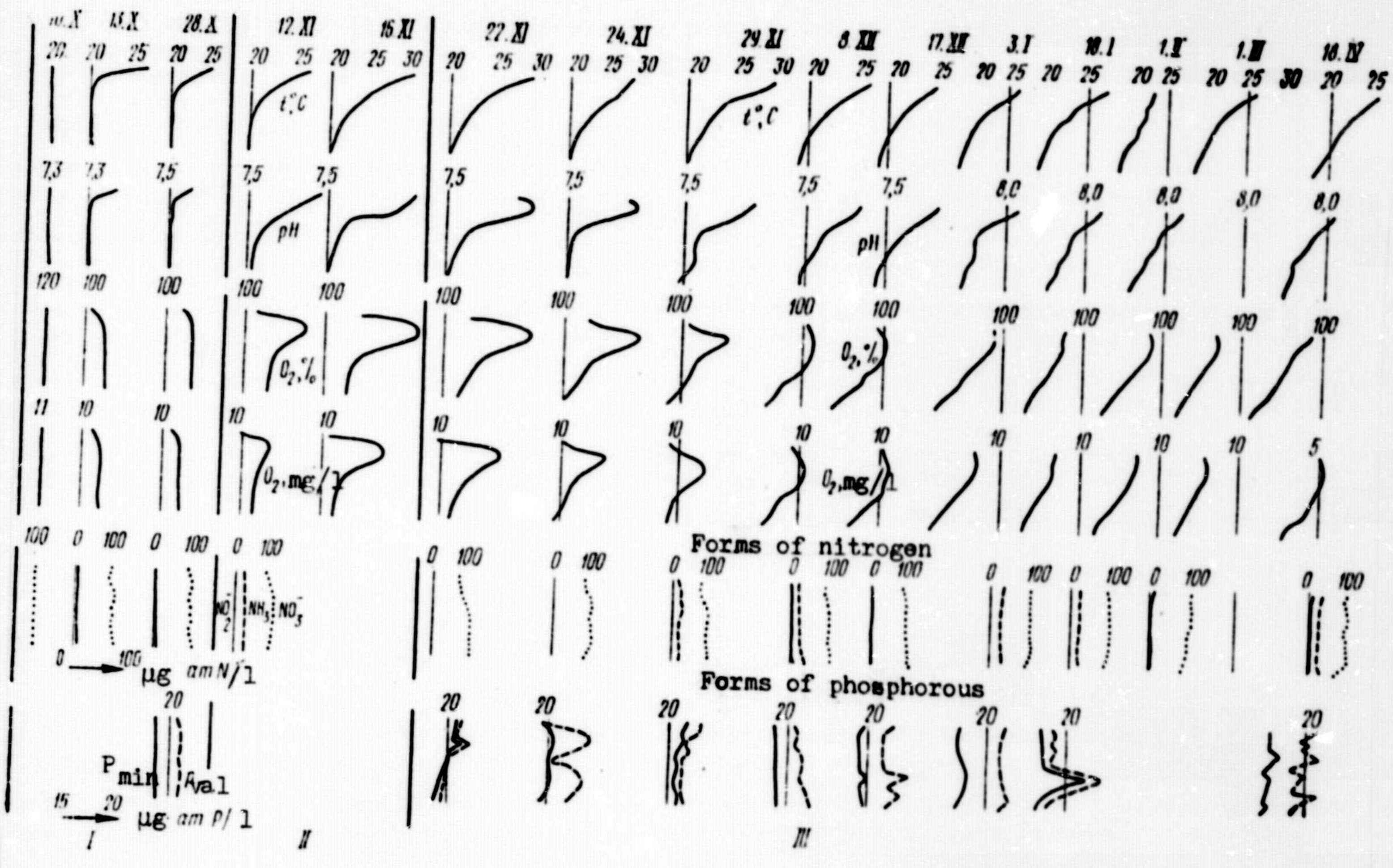

Figure 2. Course of Ecological Experiment.
Vertical distribution of temperature, pH, dissolved oxygen, organic and mineral forms of nitrogen and phosphorous. I--biogenic elements KH_2PO_4 and KNO_3 added (physicochemical processes); II--chlorella and

(continued on next page)

bacteria added (physicochemical processes, photosynthesis, destruction); III--daphnia added (physicochemical processes, photosynthesis, destruction, eating of algae by zooplankton).

etc. For control the pH and concentrations of the dissolved oxygen were determined. Finally the last group primarily included biological parameters--the species composition and concentration of phyto-, zoo- and bacterioplankton whose determination it is difficult to automate.

The first experiment that we started in October 1976 lasted until July 1977. In order to simplify interpretation of the findings we left the lamps on for the entire experiment.

The observation results are shown in figure 2 (data obtained from April to July are not given since they differ little from the data for April). In the beginning moment all the profiles of parameters, i.e., temperature, pH, concentration of oxygen, nitrites and nitrates, and others were uniform with a change in depth. The water was supersaturated with oxygen whose concentration was 120% of the equilibrium value. Heating by lamps of the surface layer led fairly rapidly to formation of a stable temperature stratification. Due to the fact that the solubility of the molecular oxygen is reduced with an increase in temperature, and oxygen concentration in the upper layer was reduced.

On 5 November algae were put into the basin--a mixture of several species of chlorella. On the next day their quantity was roughly the same on all levels and was $0.5\text{-}1.5 \cdot 10^4$ kl/ml. Already in a week the number of cells was considerably increased, while the nature of the vertical distribution was significantly altered. The maximum number was formed at a depth of 20-40 cm. At this moment in time due to intensive photosynthesis at a depth of 40 cm surface maximum of oxygen was observed. The maximum water saturation with oxygen reached 222%.

The maximum values of pH, equal to 8.4 did not coincide with the maximum oxygen content, but were noted for higher layers (depth 20 cm). Probably, such a reaction of the medium is a result of the impoverishment of the upper layer of carbon dioxide due to the reduction in its solubility and utilization of CO_2 in the process of photosynthesis. Under natural conditions, for example, in the Mozhaysk reservoir, the surface layer to depth 100-200 cm was usually mixed, as a result at different depths in it the maximum content of oxygen coincides with the maximum pH.

The maximum number of algae was observed on 15 November, when at a depth of 40 cm about $50 \cdot 10^4$ kl/ml were found. Here a sharp stratification was found in the distribution of algae: at depth 80 cm their number was only $5\text{-}6 \cdot 10^4$ kl/ml. On this day daphnia were put into the basin in a quantity of 1 specimen/ml. In the next two days the presence of crustaceans did not have any effect on the number of algae and their vertical distribution. However, already on 19 November the maximum number of chlorella, equal to $22 \cdot 10^4$ kl/ml was found at a depth of 80 cm. This was two times lower than the maximum number on the 15 or 17 November.

The balance between the production of oxygen due to photosynthesis and its consumption for respiration and oxidation of organic substance was disrupted. The oxygen concentration in the upper layer began to drop sharply, and in 20 days oxygen supersaturation was not observed in any of the levels.

By this time the number of chlorella cells was reduced to $1\text{-}2 \cdot 10^4$ kl/ml and the vertical stratification had practically disappeared. An insignificant increase in the number of chlorella was noted during 24-26 November only at a depth of 200 cm. At the end of December the number of algal cells at all the studied levels (from 20 to 200 cm) did not exceed $0.5 \cdot 10^4$ kl/ml, and in the subsequent /99
days in the thickness of the water the cells were practically missing. The oxygen concentration in the upper one-meter layer was slightly below 100%, which indicated the dominant role of the zooplankton.

During the experiment in the basin spontaneous microflora developed that mainly concentrated in the upper film. Preliminary qualitative studies of the taxonomic composition of the microbe cenosis on the basin surface make it possible to draw a conclusion on the presence of succession in this community. During the entire period of observations a natural exchange occurred of the forms of bacteria towards dominance of the oligotrophs. The actinomycetes and bacillary heterotrophs gave way to the vibrio forms of the Caulobacter and Microcycles. In February 1977 a certain stabilization was observed of the communities. One should note that in the samples taken from the mass of water, during the entire experiment the bacterial cells were only single cases, and in the majority of cases were not found at all.

In the last phase of the experiment such a production-destruction equilibrium was formed where an insignificant quantity of oxygen isolated in photosynthesis was immediately consumed for respiration and oxidation of the organic residues that precipitate out from the links in the food chain. Impoverishment of the

surface layer 0-60 cm with all forms of nitrogen was noted. The concentration of nitrates was sharply reduced. Nitrites appeared whose concentration was increased towards the bottom.

In summing the data of the ecological experiment one can state that for the first time by means of primarily biochemical processes where the role of dynamics of water is small, a pattern of vertical distribution of oxygen, phosphates, nitrates, pH and other hydrochemical parameters was successfully created. It is difficult to overestimate the result for in natural reservoirs we can never isolate the effect of hydrodynamics and biochemical processes. The concentration of any of the biogenic components at a certain depth is determined by the complex superposition of these processes.

In developing these studies one can obtain all the necessary coefficients for compilation of a mathematical model of water biocenosis. The construction of such a model will permit control of the hydrochemical and hydrobiological pattern of reservoirs, and consequently, control and prediction of the quality of water.

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